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"CYBERNETIC INTEGRATION OF EXPERIMENTS
INTO THE CVT SYSTEM"

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Final Report

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FINAL REPORT

PREAMBLE

The research work funded by the Grant NGR-43-001-117 of the NASA Marshall Space Flight Center progressed in the following manner. February and March 1972 were used to:

- 1) Assemble a large number of titles of promising experiments. From those NASA will select those few which will be used in the CVT in simulated orbital flight, yet under one G conditions.
- 2) Develop a cybernetic model which is a static aggregate of the existing interactions in the CVT.
- 3) Develop a dynamic PERT/COST model which will be used for the integration of man-experiment-environment in the CVT for those experiments which have been designated by NASA for flight. Hereby the critical path will not be developed because no completion limit for the experiments is set and the experiments are terminated after the arbitrary flight times.
- 4) Provide and develop the necessary food for the four crew members (at no cost to NASA) for the first few flights (not exceeding 30 days).
- 5) Develop an experiment which evaluates the provided food, as far as its influence on the psychophysical effect and performance of the crew are concerned.
- 6) It is understood that during the present six months Phase A of the grant, only the plans are generated and the fundamentals developed. The implementation, control and evaluation of the on-board experiments should be performed in Phase B, which will be the subject of a separate grant.

INTRODUCTION

The type of study proposed for the Grant on the "Cybernetic Integration of Experiments into the CVT-System" is based on attempts which, in a very primitive form, have been made by a number of investigators.

Probably the first in this line was Quesnay, who in 1758, published his book "Tableau Economique Avec Son Explication et les Maximes Generales du Government Economique". Much later, Keynes developed his "General Theory" and then in 1939, Harrods published his "Essay in Dynamic Theory" and Samuelson "Interaction Between Multiplier Analysis and the Principle of Production Acceleration". More recently, these rather analytical treatise were combined with cybernetic control functions by A. Tustin (1953), A. W. Phillips (1954), R. G. D. Allen (1956). Special attention should be given to the book by H. Geyer and W. Oppelt "Economic Control Functions" (1957), and C. Fohl "Higher Order Economic Control-Loops in Analog Models". The first mathematical model in this field which lends itself to computer application was described by Jay W. Forrester in "Industrial Dynamics" (1961). Further advancement, useful for our work, is described by N. Brachthauser, "Betrachtungen über den Funktionsmechanismus des Endogenen Teils der Konjunkturschwenkungen" (1967).

Our approach to the integration of experimental activities into the CVT-System has the objectives:

- 1) Improvement of the analytical evaluation of the dynamic processes of man and equipment in the CVT.
- 2) Improvement of predictions and prognoses for compromises and malfunctions in the CVT-System in the seven-day to thirty-day time domain.

3) Improvement of individual goal-directed activities in function of goal-attainment.

4) Establishing a realistic basis for the cost-effectiveness of the CVT operation.

PERFORMANCE

1) The goal set in "1" of the preamble has been achieved. There have been experiments topics assembled (see Appendix A).

Much time and effort was spent to obtain the experiment program of the defunct MOL project to utilize the large amount of the tax payers' money which was spent in that project. The great part of these experiments are unclassified. Nevertheless, it was not possible to get the information from the retired files.

A list of experiments designated but not used for the "Skylab" (see Appendix B) were examined for possible utilization in the CVT.

All of these experiment topics are now available to NASA for the decision in the selection of the designated few experiments for flight. As soon as this decision is available the work on their cybernetic integration into the CVT System will continue.

2) Due to the highly complex dynamic system of the cybernetic model: Four man Spacecraft (including life support navigation, experiment support)--set of experiments (including hardware, facilities, communication, data processing), the model is most complicated. If only theoretical considerations would be required, then many simplifications and approximations would be satisfactory. But, in this case, we want practical results for the CVT, thus high fidelity of the model is imperative, which, in turn, does not tolerate the omission of details. For the demonstration of the effort which went into this model in the short time spent so far

some raw sketches are attached under Appendix E.

3) Toward the goal, described in "3" of the preamble, we made good progress and a number of approaches are in the developmental phase.

a) It is assumed that competition of the crew is restricted to the two experimentators, although the two ship crew will interact with them and their operational decisions may have significant influence on the experiment performance. Because of the limited facilities in the CVT the operation of the experiments will be based on a set of compromises which puts the two PI's into competition. Therefore, I started on two different mathematical models (Appendices C and D) which should give us insight into the optimization of such situations. These are considered important but they require much more time and effort to finalize.

b) I have some sketches concerning the PERT/COST model, whereby the COST phase is neglected for the time being. These sketches are not yet mature enough to be incorporated into this preliminary program, which encompasses one man/month effort for "1" through "5" as described in the preamble.

4) The requirements described under "4" of the preamble have been accomplished. The proposed food supply for the first seven-day flight is designed and available.

5) Some of the objectives for the experiment concerning food acceptance, palatability have been developed, and a practical and inexpensive tool for the measurement of the crew performance designed. The values provided by the device are obtainable in three minutes, and are in good congruence if obtained in repetition from the same individual. They give good relative and comparable values, also for the assessment of the performance of different persons. The building of the prototype of the Helvey pursuit-tracking-mater will be accomplished in Phase B and could be available at the first CVT Flight.

6) Although not the subject of the Grant, but because of its pertinence to the requirements of "5" above, a selection of psychophysical factors are listed in Appendix F which should be considered by the medical team which will be in charge of the health status of the crew during flight.

APPENDIX A

A. Experiments involving Man but Necessary for Cybernetic Integration.

- 1) Human Performance decrement during the conduction of experiments (Fatigue syndrome).
- 2) Intra-ship communication system, (Interference and noise free system).
- 3) Food selection and palatability study with reference to performance. The effects of re-cycling.
- 4) Development of special forms of communication in event of failure of auditory modality.
- 5) Small group interactions under long-term CVT conditions.
- 6) Laser communications system for orbital information exchange.
- 7) Remote sensing system with man in the loop as coordinator.
- 8) Development of global educational systems.
- 9) Establishing the operational loop with human component for experimental programs.
- 10) Optimizing all information displays with attached control functions as a unified system for experimental and life support factor.
- 11) Define areas of information acquisition by instruments where human judgement can be used to reduce data pollution.
- 12) Feasibility of man-controlled information management.
- 13) Design of software for data-processing and data analysis for on-board information.
- 14) Application of satisfaction functions to decision theoretical requirement, with regard to crew decisions for the maintenance of the operational integrity of CVT.
- 15) First order interactions of man with visual targets for reference coordination.

- 16) The role of food acceptance and palatability in the performance of the crew, with reference to operational error.
- 17) Motor and mental fatigue effects on the efficiency of the man-machine interface.
- 18) Time and motion study of routine activities and bench-research.
- 19) Programming logistics for on-board experiments, in terms of instrumentation compatibility.
- 20) Programming of time compatibility for experiment execution.
- 21) Unified workspace layout for experiments.
- 22) Assigning man-machine tasks in pattern recognition for partial or total failure analysis.
- 23) Cybernetic approach to the multi-man, multi-system management.
- 24) PERT/COST and critical path design of MDS fabrication.
- 25) Determination of measurability of research results for application of computer processing.
- 26) Utility of "AMTRAN" in on-board information management.
- 27) Applicability of principles of process control on experiment execution.
- 28) Laser communications, space station-to-ground:
 - (a) Accommodates high information rates (bandwidth)
 - (b) Use with TV or any high data rate requirements
- 29) Coherent Optical Data Processing:
 - (a) Pre-processing of data and/or imagery such as remote sensed earth resources data
 - (b) Can be employed to "filter out" or remove undesired or redundant information prior to transmission of such to earth (allows reduction of transmission rates and bandwidth)
- 30) Laser ranging (analogous to Radar ranging):
 - (a) Potential use in docking manuevers, tracking, velocity measurement.

31) Synthesis of compounds under zero G from molecular gold and carbon.

B. Experiments of Lower Priority

- 1) Design of multi-purpose research equipment.
- 2) Design of zero G research tools.
- 3) Development of experimental kits suitable for experiments and measurements which were not predetermined.
- 4) Optimization of intravehicular communication.
- 5) Establish zero G base-lines for multi-sensory human information acquisition capabilities.
- 6) Coordinate human factors experience with Dr. Polstorff in Skylab, ATM.
- 7) Evaluate systematically the debriefings of returning astronauts with regard to man-machine interface.

C. Experiments which may have to be discarded due to their Assignment to the Manned Space Flight Center

- 1) Study of specialized food for:
 - (a) Increasing motivation.
 - (b) Enhancement of sensory capability.
 - (c) Extra source of energy for stressful situations.
 - (d) Correction of medical problems.
- 2) Design of substitute for water as detergent, hygiene, shaving, etc.
- 3) Power supply as source of water (electrolytic, fuel cell, etc.).
- 4) Determination of optimal humidity to long-term performances.
- 5) Design of supplies and equipment for personal hygiene and entertainment, etc.
- 6) Remote control system for extra-vehicular experimentation.
- 7) Study of human adjustment to extreme isolation.

- 8) The fate of the fecal bacterial flora in a long-term closed ecological system.
- 9) Man-machine interface studies with reference to psychomotor functions for CVT tasks.
- 10) Test the psychological response of crew types to various environmental parameter in the MDS.
- 11) Effect of sleep-wakefulness cycle on the efficiency of the man-machine interaction.
- 12) Effects of sensory deprivation as experienced in the CVT under flight conditions.
- 13) Human sensory accuities and limits under zero G conditions, with special reference to CVT tasks.

EXPERIMENTS DESCRIBED IN SOME DETAIL

1. Critical Temperature Measurements

Objective:

Critical temperature measurements are convection and thus, gravity dependent, which impairs the accuracy of the data obtained. Therefore, it would be of significant scientific interest to determine this fundamental factor under zero G condition.

The gravitational field causes a density gradient in the highly compressible fluid which exists near the critical temperature. There are a number of methods applied to minimize its effect, but the best is the elimination of gravity. The obtained information may have significance in liquid fuel management in space.

Experimental Program:

The experiment consists of introducing various gases or liquids into glass tubes, place them in a controlled

temperature jacket, and measure, through light, scatter, the disappearance of the second phase. The three gases, proposed for testing are carbon dioxide ($T_c = 31.0^\circ$), ethane ($T_c = 31.1^\circ$), and nitrous oxide ($T_c = 36.5^\circ$).

It is anticipated that there will be significant differences in these values if measured in orbit.

Volume, Weight, and Power Requirements:

Table top requirement-2 x 3 ft. with 2 ft. clearance
Storage requirement-8 ft³

Total current requirement-1.5 watts/hrs.

Man in the loop-100%

Other support-none (except general tools)

Computer storage-30 minutes batch

Computer core-10 minutes

Duration of total exp.-50 hrs.

2. Using a Laser to Measure the Index of Refraction of a Gas

A Michelson Interferometer is set up using a beam splitter and two front surface mirrors. A small chamber with glass windows at each end is placed between the beam splitter and Mirror M-1. This arrangement results in some of the light from the beam splitter going through the chamber twice (once in each direction) before it hits the viewing screen. The rest of the light from the beam splitter strikes Mirror M-2, which also reflects it to the screen.

By making small adjustments to mirrors M-1 and M-2, the two beams can be superimposed on the screen and a diverging lens will expand the display to show alternate dark and bright interference bars, or fringes.

Air in the chamber is removed with a vacuum pump and then the valve is opened slightly to let the air or pollutant leak back in while the investigator counts either the dark or the bright interference fringes moving across the screen.

Light travels slower in air than it does in vacuum. This has the same effect as lengthening the optical path through the chamber. Thus, each fringe shift represents an increase in distance equal to one wavelength of light (6328A for a He-Ne Laser). By comparing the optical path length in the evacuated chamber with the apparently increased length when the chamber is filled with air (or other gas) we can find the index of refraction of the gas:

$$n = \frac{2L + N}{21}$$

where:

n = index of refraction

N = Number of fringes moving across the screen

= wavelength of light (6.328×10^{-5} cm for a HeNe Laser).

L = inside length of gas chamber in cm. (optical path is $2L$ because light goes through the chamber twice).

3. Earth Observation Experiments

Experiments are designed to monitor Earth activities in the area of planning and marketing crop census and yield estimates. Continuous man-monitoring in this field should yield to optimized management technique. Other activities are improvement in fishing productivity in biologically rich areas. With man on board, marine navigation and improvement in rural and urban development, should be conducted routinely.

The equipment to be utilized consist of multispectral scanner, photographic, spectrometer, passive, and active microwave detectors. The on-board operation will consist of, operating the mentioned apparatus, data analysis, optical facility for the support of the experiments for optical alignment, calibration, etc.

4. Interfacial Biophysics of Thrombus Formation

This project includes assessment of the initial absorptive events involving blood components at various phase boundaries with special attention to their sequences, rates, and differentiation into fractions of specific densities (lipids versus proteins, for instance). Preferential lipid accumulations at vessel walls, known to be precursors of sclerotic plaques, will be analyzed. Background and philosophy are reviewed in the paper, "Role of an Artificial Boundary in Modifying Blood Proteins", Fed. Proc. 30: 1523, 1971.

5. Improved Enzyme Immobilization on Solid Substrates

Numerous useful biological and technological processes, ranging from enzyme-catalyzed commercial syntheses to extra-corporeal fibrinolytic prosthetic circuits to combat intra-vascular thrombosis, depend upon proper fidation of absorbed proteins (in still-active configurations) to "carrier" surfaces. The prospects for improved infiltration and absorption of proteins within porous beds of a variety of substrates, taking advantage of "weightless" states where surface forces predominate, will be assessed. Theoretical and practical factors which must be considered are presented in the paper, "Adhesion: Mechanisms that Assist or Impede It", in Science 162: 1360, 1968.

6. Chloroplast Activity During Low Energy Nuclear Radiation

It must be assumed that by the time of interstellar travel the problem of artificial photosynthesis will be solved. Or, other means of human gas exchange will be found. But, interplanetary travel may come about before the state-of-the-art of the homeostatic closed ecological system is advanced far enough to eliminate the need of the chloroplast as a gas exchange vehicle. Thus, photosynthesis will be a condition sine qua non for space travel.

As long as the space ship will operate in the vicinity of Earth, Venus, or Mars with an average photosynthetically active solar radiation of about $0.8 \text{ cal/cm}^2/\text{sec}$, no difficulty is anticipated from this point of view. Should the field of operation, however, reach Jupiter or Pluto, the solar radiation would be insufficient to maintain the required photosynthetic activity. The answer is, of course, that by that time the nuclear power plant of the ship will provide an ample source of energy, which could be converted into photosynthetically useful radiation. However, as long as we will learn to utilize interstellar free radicals as fuel by scooping it up in some sort of astro-ramjet, any fuel will be a scarce commodity, and the greatest economy is indicated in the use of the power plant. Therefore, it would be of great interest to be able to utilize cosmic radiation or maybe the waste Bremsstrahlung from the power plant for the CO_2-O_2 conversion. The prerequisite for this would be the intimate knowledge of the photosynthetic mechanism.

According to the generally accepted theory the source of energy for photosynthesis is derived from protons which bring about the fission of water molecules and create hydrogen radicals.

It is thinkable that the acceptor is not shielded by specific molecular bond configurations and will pick up hydrogen radicals whenever they occur within the sphere of polar attraction. If so, it becomes very probably that

photosynthetic reduction of CO_2 should occur if hydrogen radicals are formed by ionizing radiation.

The probability of a success for such experiments is greatly enhanced by recent findings, namely that CO_2 reduction can occur in the absence of light and that the hydrogen for the reduction processes can be obtained from sources other than water, such as hydrogen sulfide or molecular hydrogen. These indicate the accessibility and high degree of polarization of the hydrogen acceptor.

This experiment has the only aim to determine whether the radiation has any effect, and if so, will radiolysis of water render an increased or decreased quantum yield as compared with photolysis.

7. Vitrification of Substances Under Zero-G

The production of new glasses using systems which do not form glasses in 1-G environments is proposed. The accomplishment of this objective is proposed using systems which do not form glasses near their composition range and with compositions near presently known glasses. The glasses to be produced for prediction of glass properties of glasses which cannot be made in a 1-G environment will be characterized using electrical, magnetic, and electron microscopic techniques. A demonstration of one type of glass formation during free fall is proposed.

8. Casting of Structural Plastic Sections in Orbiting Space Station

Light weight reinforced structural plastic material systems offer the advantages of high specific strength and resistance to environmental degradation which makes them appealing material systems for space construction. An obvious packaging and space optimization problem arises in transporting

precast sections into space. Transportation of the basic matrix material in liquid form and the reinforcing fiber in rolled or coiled form enables an optimum solution to the packaging problem, i.e., minimization of the required space.

The proposed experiment induces the casting, on a relatively small scale, of the reinforced plastic sections in space. A simple casting technique of this type has been developed at Vanderbilt, primarily for the purpose of developing photoelastic test specimens of various properties for the purpose of experimental stress analysis. It is proposed to adapt the present technique to a space environment experiment.

# BELLCOM	# NASA	TITLE	TECHNICAL CONTACT	SPONSOR	DOCUMENTATION	HARDWARE STATUS
EJ 0147	M072	Bone Densitometry	Texas Womans College /Diettein, L. F.	OMSF	Definit. Exper. Plan 01-66 NASA Form B47:15-V-68	
EJ 0302	W44	Metric Camera	Coast & Geodet. Surv.		NASA Form ii38:15-X -65	HW funds tentative available
EJ 0315	T 018	Precision Optical Tracking	MSFC/R-ASTR-RP /Wyman, C. L. 3-3770	OART	NASA Form 1067:19-VIII -65	HW avail., cannibal.
EJ 0476	T 017	Meteoroid Impact & Erosion Experiment	MSC/Burbank, P.	OART	NASA Form 1067/1138	
EJ 0570	S 051	Daytime Sodium Cloud Experiment	Centre National de la Recherche, Paris	OSSA	NASA Form 1067:05-V-66 NASA Form 1138	
EJ 0663	S 061	Potato Respiration (as a function of biorhythmicity)	Space/Defense Corp. /Ross, M.	OSSA	Exper. Implem. Plan 07-XI-66 NASA Form 1067:12-XI-66 NASA Form 1138:12-I-66	
EJ 0672	T 021	Meteoroid Velocity	MSC/COUR- Palais, B.	OART	NASA Form 1138:26-V-66	
EJ 0683	D 021	Expandable Airlock	Wright-Patterson AFB/ /Col. Hemsley, R.	DOD	NASA Form 1138:19-IX-66 Defin. Exper. Plan:10-I-67	
EJ 0713	M 507	Gravity Simulation Workbench Experiment	MSFC/S&E-AERO/ Holderer, O. /Few, A		NASA Form 1138:28-XI-66	HW available
EJ 0770	M 508	EVA Hardware Evaluation	MSC	OMSF	NASA Form 1347:04-IV-67	
EJ 0846	T 029	Pilot Describing Function (A)	Ames RC	OART	NASA Form 1339:22-X-68	
EJ 0861		IR Interferometer Spetrometer		OMSF	NASA Form 1346	
EJ 0868	M 132	Neurological Experiment - EEG	UCLA/Baylor, V.	OMSF	NASA Form 1339:6-VI-68 NASA Form 1347:6-VI-68	
EJ 0941	L 098A	Potato Respiration Biorhythms	Space/Defense Corp. /Scott, C. M.	OMSF	NASA Form 1346:13-X-69	

APPENDIX C

MODELING DYNAMIC INTERACTIONS FOR TWO COMPETING SYSTEMS

The cybernetic approach to the triadic system in the CVT project involves man-equipment-environment. However, this first approximation does not reflect on the complexity of the system and an analog model can be constructed only in discrete steps. Although it must be borne in mind that such an approach constitutes a systemic error which can be eliminated; however, by tying together cybernetically the individual subsystem output.

The basis of the model is the simultaneous performance of two independent experiments with two men in the loop, competing for facilities in the same time-domain. The solution of the cybernetic problem is the optimization of the system dynamics with reference to cost effectiveness, subsystem (individual experiments) compatibility, space, and support utilization, inter-personality interactions (small group dynamics) and research results and their documentation.

The best approach to a speedy solution of the problem is a simultaneous treatment of theoretical and empirical parameters and let them converge toward the time limit of the contract.

In first theoretical approximation, one can consider the two investigators and their experiment as system S_1 and S_2 and the information about their program and personality $I_1(t)$ and $I_2(t)$ at the initial time t .

Systems S_1 and S_2 are in competition for all factors which are necessary to complete their task best, fastest, and with minimum stress.

As they perform their program, there is a continuous change in the information representing their activities. We assume that the rates of change of information of both systems are governed by the following equations:

$$\frac{d}{dt} I_1(t) = A_1(t) I_1(t) + B_1(t) I_2(t)$$

$$\frac{d}{dt} I_2(t) = A_2(t) I_2(t) + B_2(t) I_1(t)$$

Where $A_1(t)$ and $A_2(t)$ are coefficients of proportionality, dependent on the time t , and $B_1(t)$ and $B_2(t)$ are coefficients of interactions of the two systems at the time t , such as operational requirements of space or support items.

Suppose that system S_1 is aware of the coefficients $A_2(t)$ and $B_2(t)$ for the time interval $0 \leq t \leq t$, and the given condition:

$$I_1(0) > I_2(0)$$

is satisfied, then the optimization problem for system S_1 is as follows:

The coefficients $A_1(t)$ and $B_1(t)$ are to be determined for $0 \leq t \leq t$, such that:

$$(i) \quad I_1(t_1) - I_2(t_1) \geq d_1$$

whereby d_1 expresses how far system S_1 wants to be in advantage of system S_2 concerning mutual commodities at the time t_1 ;

(ii) a certain cost function C_1 , which refers to the utilization of available resources and has to be specified, is minimized.

We assume that system S_1 obtains the coefficients $A_2(t)$ and $B_2(t)$ for $0 \leq t \leq t_1$ by prediction from values of $A_2(t)$ and $B_2(t)$ for a preceding finite time interval $-T \leq t \leq 0$ whereby $A_2(t)$ and $B_2(t)$ are considered as non-stationary random processes and the prediction is made on basis of the theory of non-stationary stochastic processes by Godfrey.*

*Advanced Seminar, US Army and Statistics Dept., University of Wisconsin, Madison, 1966.

This procedure has to be repeated for the following time interval $t_1 \leq t \leq t_2$ when the time $t = t_1$ is reached with another constant of advantage d_2 and associated cost function C_2 , where prediction of $A_2(t)$, $B_2(t)$ for the time interval $t_1 \leq t \leq t_2$ has to be made from the time interval $-T \leq t \leq t_1$.

In the general case, at the time point $t = t_n$, the problem is given for the time interval $t_n \leq t \leq t_{n+1}$, with the constant of advantage d_n and cost function C_n , and using the time interval $-T \leq t \leq t_n$ for the prediction of $A_2(t)$ and $B_2(t)$ in $t_n \leq t \leq t_{n+1}$.

APPENDIX D

ASPECTS OF MAN-MAN INTEGRATION IN THE CVT

The interpersonality interaction between the investigators or experimentators in a space vehicle is by definition a typical case of competing complex systems. Due to the restricted resources in the spacecraft, the goal attainment of the two or more diversified goal-oriented activities will stress each other's homeostatic and homeodynamic equilibria. The success of such perturbation and the elastic resistance of the individual systems are energy and time consuming which, no doubt, will cause performance decrement in the total system's output. Therefore, a cybernetic integration will greatly enhance the cost-effectiveness of the system. This is further emphasized by the fact that a complex system with rigidly controlled parameters, as is e.g. the CVT, is quite unforgiving to human errors. Hence, carefully predesigned error sensors and error correcting feedback loops are essential for acceptable system output.

Particular difficulty arises when the commodities for the performance of the experiments are, as it must be in a space craft, in short supply. If the design of the dynamic system of experiment performance is properly done, then any excess must be reserved for the repair of unforeseeable malfunctions.

Looking here at the mutually assured operating relationship of the experimentors, called in the following P.I.'s, one must assume that their competition for commodities increase their aggression above an acceptable low level. Therefore, it is advisable to investigate analytically the existence and the behavior of such relationship. Mathematical models provide a rapid means for estimating bonds and sensitivities which take into account interactions usually neglected in first approximations, and they provide a flexible and inexpensive tool to investigate the general nature of such strategic relationships.

The purpose of the insertion of this chapter in the report

is to demonstrate the feasibility of such undertaking. Of course, one must confine this model to the examination of the relative cost and effectiveness of the applied parameters under a set of assumptions. This is a calculated risk for systemic errors.

The key parameters are related to the capabilities and vulnerabilities of the character of the opposing PI's. Let us assume that in this simplified model two (n) PI's are experimenting who are involved in maintaining a mutually assured operating relationship by pursuing that posture at least cost. Hereby "cost" can be time, space, energy, or materials.

It should be mentioned here that if $n > 2$, most likely temporary coalitions will be formed. but if such alliances are reliable, than they can be considered as a single element. Such cases will not be treated in detail in this report. For simplicity's sake, let us stipulate that all aggression is expressed in arguments, although by long missions the stress sector may result in other overt behavior, which can and should be modeled if the mission duration exceeds a couple of months.

Let the number of valid arguments of PI_1 be A ; and suppose he believes that this is sufficient to deter PI_2 from using his commodities. We further stipulate that each of arguments A contain "f" truth values which have a probability of P_{2j} to override the other's argument. Of course, in case of coalition their larger number of "f" has a higher efficiency in the struggle. It is also assumed that both PI's are prepared to argue and insist about their rights to use the available commodities.

In case of an encroachment of PI_1 commodities by PI_2 , he is using a set of arguments nA_j against PI_1 with a set of F_j . The remaining argumentative weapons $A_i(F_j \cdot A_j/A_i)$ are applied at random against PI_1 's arguments. The probability that any of PI_1 's arguments will be successful is:

$$(F_j \cdot A_j/A_i) \cdot (1-p_{ij}) \cdot (1-P_{ij} (F_i A_j/A_i)) = K$$

which becomes:

$$\prod_{j=1}^n K_j = L$$

if PI_2 represents a group of persons, and the expected number of successful arguments on PI_1 's part is than: $A_1 L$

The condition for maintaining a mutually assured operational relationship is expressed by the group of inequalities:

$$A_i \prod_{j=1}^n (1-P_{ij})^{(F_j \cdot A_j/A_i)} [(1-P_{ij})(F_i A_j/A_i)] \geq \sum_j Q_{ij} = Q_n$$

where $n = 1, 2, \dots, n$

Such a group of inequalities has always positive solutions for A_i for all $P_{ij} < 1$. Given any A_i 's multiplied by a positive number of r , the product terms on the left remain unchanged but the factors $r A_i$ can be arbitrarily large. Thus, by choosing a large enough multiplier all the inequalities can be satisfied. This indicates that the mutual assured operational relationship is independent from F_i , P_{ij} , and Q_{ij} as well as the number of PI 's in the craft. Thus, a solution always exists but due to the complexity of the model by more than two PI 's the generalization becomes harder to manage, because this parameter is non-linear.

In presenting an argument the individual PI 's intelligence is an important factor, but according to this model the disadvantage of a lesser intelligence can be overcome by an increase of the number of arguments.

Another factor can be also considered here, namely the cost, or the time and effort spent for the argumentation, which will have a similar reaction on part of the other PU . This will lead to diminishing returns, which, in turn, adds to

the stability of the solutions, and the possible ambiguity of the mutual communication will not lead to unlimited argumentation.

It could be argued that the solutions of the above model could be easily obtained by "common sense", but this only indicates that the brain is a good problem solved and that the model could be used to a rigorous cybernetic integration of this aspect of the CVT system.

APPENDIX E

ESTABLISHMENT OF THE OPTIMAL NUMBER OF RESEARCH CREW FOR THE CVT

INTRODUCTION

The purpose of this report is to present information necessary for the establishment of the optimal number of the research crew for the Concept Verification Testing (CVT) vehicle.

There are several ways to approach this problem. However, most of these would require an analysis of the proposed experiments for each discipline and a complex operations research approach to the solution.

The information presented in this document takes the approach that avoids the complex analysis of the experiments and is based on crew selection primarily from the human factors standpoint.

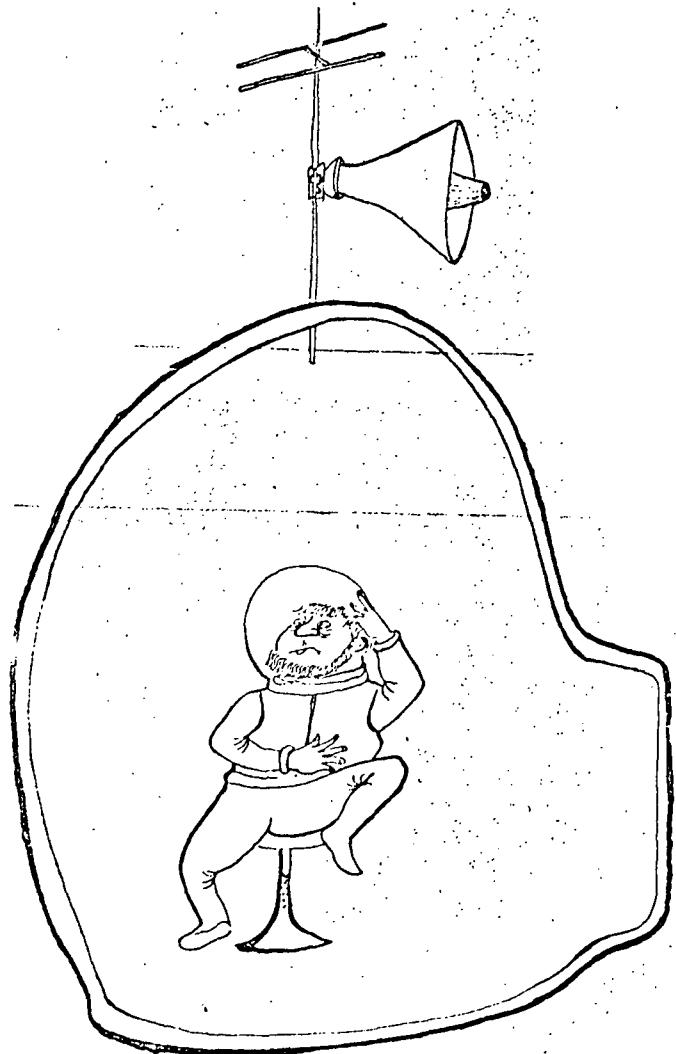
SINGLE-OPERATOR PARAMETERS

The most desirable weight-saving method of staffing the CVT would be to occupy it with one man. The expected demands of the mission, however, far exceed the capabilities of a single operator.

The most obvious factor in the task, as it is envisioned for a CVT research operation, is the high degree of attention which the mechanical system of the base will demand without letup. The many unknown factors and possibilities, as well as communication with earth, will require continuous monitoring which would not allow time for rest. Another argument which would exclude the one-man system is evident from the necessity of permanent vigilance for emergency situations, such as a meteorite strike. Furthermore, the mission profile of the CVT is mainly concerned with the collection of scientific data and the gathering of such information will involve expeditions outside the CVT. The elements of safety will therefore require that at least one person be stationary in the CVT to supervise the equipment and to monitor the activities of the person outside the CVT.

It is not inconceivable, however, that after the reliability barrier of the equipment has been broken through at some later

period, some low-stress, short-sleeve mission profile can be designed which could fall within the capabilities of one operator.



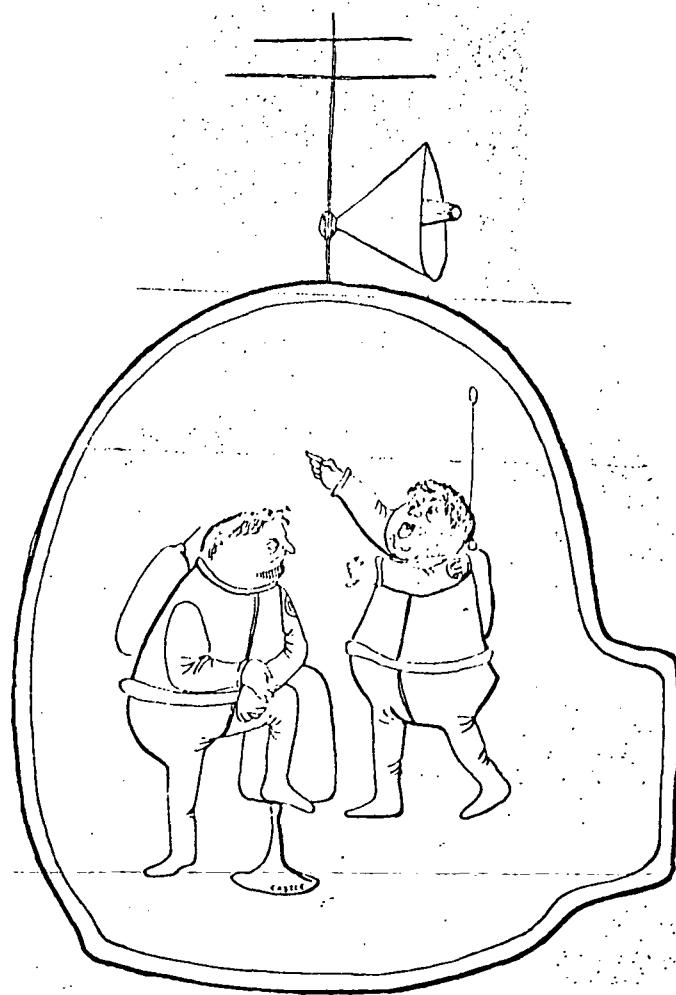
DUAL-OPERATOR PARAMETERS

Two Males

The next progressive step in the choice of the minimum optimal crew number would be the selection of two male personnel. Again, the length of the mission and the requirements of equipment and research duty are overwhelming.

Even if the work cycle were arranged in a manner such that one operator would always rest while the other works, the situation would not be improved over the one-man system operation. Forwarding information to earth, maintaining the CVT equipment, and functioning on the outside of the CVT could not be carried out by the one working individual while the other is resting.

The social interaction between two men living together for a prolonged period in the cramped environment must also be taken into consideration. If hostility is to be avoided, interaction



must be achieved and should occur in a satisfying manner. The necessity of duty in a two-man system would leave each operator so exhausted that sleep would be a treasured reward and could eliminate therapeutic and relaxing idle association.

Much research is expected in the CVT prototype for the investigation of the possibilities of two-man operations of a less taxing nature. Orbital flights and missions lasting under two weeks could perhaps be more economically accomplished using such a crew number. Some of the interesting problem areas there would involve personality frictions, work and rest cycles, diversion, duration of duties, etc.

One Male and One Female

Another combination also should be mentioned: a team composed of a man and a woman. However, certain missions may require a taxing physical burden with which the female physique could not cope without severe performance decrement. In addition, the compensatory behavior of the male in such a situation would perhaps be detrimental to the total team output due to fatigue and emotional stress.

THE THREE-OPERATOR SYSTEM

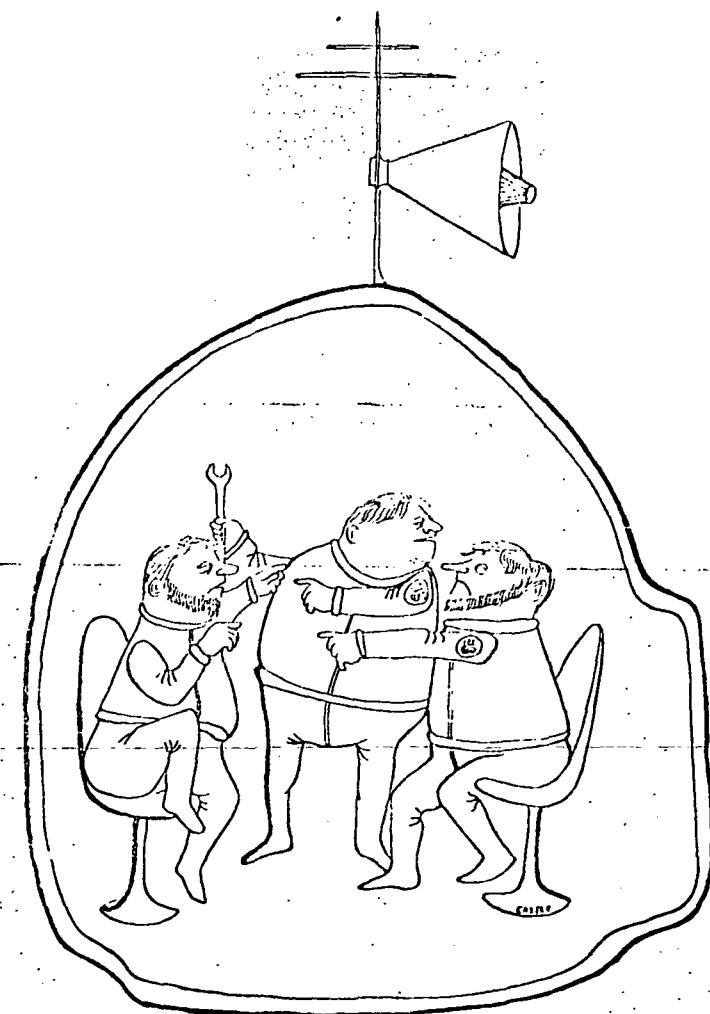
The selection of three individuals for the optimal minimum CVT crew complement seems to provide the most efficient means by which to complete the mission. Although more than three personnel might be desirable for the over-all success of the mission, weight and space parameters will set severe limitations to any greater number at least in the near future.

With the use of three humans, it is far simple to design a work-rest cycle by which one person is at rest at any given time, with the two remaining to carry out experimentation and system maintenance.

Under such a schedule, recreation and other boredom relieving factors could be utilized with greater frequency and for more sustained time periods which could be realized with crews of a lesser number.

Work involving the operation of a human outside the ecosystem requires close visual or radio contact with another operator who is safely within the CVT. In case of emergency, imminent and direct aid requirements can be met and the CVT would still contain a human who could serve until the emergency situation is dissipated. With a number smaller than three, such a basic pattern could not be realized.

In considering a three-operator system for the proposed CVT prototype, we are aware that power coalitions may tend to form, thus disturbing any preselected command chain. A CVT prototype can be used to validate various theories of coalition formation within triadic systems.



For a mission of the length envisioned for the CVT, it is most important that efficient and compatible personnel be grouped as a crew. Less obvious is the pertinence of the ratio of sexes in such a unit.

The experience of the Navy for situations of close confinement for lengthy, womanless periods has shown that such groups can stay operational for as long as many months. These experiments, however, cannot be extrapolated for the conditions as they will prevail in the CVT. Because weight considerations set extreme limitations on the crew number, the individual task burden can be satisfactorily carried only if the crew is operating with maximum efficiency. Therefore, contrary to the Navy experiment for ships or submarines, even minor irritations and interferences which could be psychologically or physiologically detrimental to the performance must be avoided.

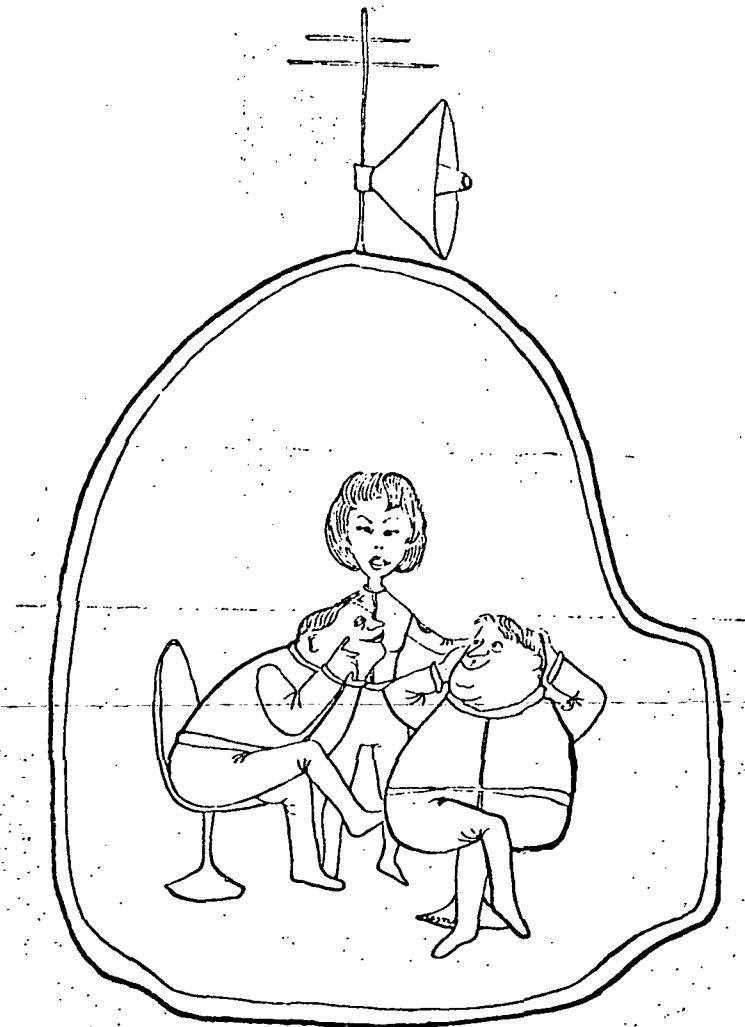
Proposed Optimum: Two Men and One Woman

These considerations have led to extrapolations from fundamental western social traits and limited influences to the hypothesis that a ratio of two males and one female might provide a more proficient crew combination. There are a number of arguments which indicate that such a ratio would have definite advantages over a system utilizing three males. The cultural suppression of hostility and, to a lesser extent, inhibition of sexual tendencies would perhaps operate more efficiently than in a system where only same-sex peers are involved. Aggression, whether overt or internalized, seems to be a function of growing or dis-inhibited hostility. This could be detrimental to a CVT mission, and it could greatly alter its functional profile. Thus it must be eliminated.

In addition, the woman in the system could have the effect of providing an inhibitory catalyst on aggression through the action of the cultural feature, and her presence would elicit the tendency of the male to display himself positively before the female. These factors could have the property of prolonging the

essentially healthy emotional atmosphere within the CVT and could also minimize the influence of hostility where it did appear. Such inhibition would imply no more stress than any similar earth-bound situation, at least for a considerable length of time.

As the mission lengthens into weeks, however, the curbs, more or less unconsciously imposed by cultural influences, may have to be partly supplanted by verbal inter-diagnosis among the crew. This constitutes an intellectual airing of problems that could greatly add to the emotional adjustment. It is expected that there may appear some cases where some individual may prefer self-analysis and control over the aforementioned therapeutic methods. The type of persons selected for the CVT operation will have to have the fundamental ability to analyze group feelings, verbalize or compensate inwardly, and adjust their behavior to maximize the possibilities of optimum crew member interaction.



Channeling of unavoidable sexual and hostile energies into areas of usefulness to the mission is a basic requirement. Libidinal energy may even have the function of incrementing the performance of certain individuals. Hostility, although recognized as irrationally derived, could be nurtured by such an individual as a promoter of his over-all drive level. In any case, the alleviation of detrimental effects resulting from sex tensions and hostile tendencies should not preclude examination of their basic origin as a continuous function of insight.

It can be considered as a great advantage of the proposed CVT prototype that psychological testing and performance observation of the personnel and its specific training can be carried out under high-fidelity simulated conditions which would give an opportunity to experiment and observe the degree of integrative or non-integrative coping with problems displayed by the individual crew members.

Should fatigue or emotional stress reach a point where the performance output begins to drop off severely, it may be necessary to utilize drugs or certain relief methods to assure a return to the expected level of operation. Part of the study of the CVT prototype would extend to determine the long-term effects of such depressants, stimulants, and other psychomimetic drugs on the over-all performance. The possible decrement arising from the use of such drugs could be evaluated and compared with the adjustment which they would provide.

In arriving at the basic optimal crew complement of two males and one female, the question of possible malfunction in the system as a result of human factors was not overlooked. Some of the suggestions as to what particular aberrance in the social field might result in lowered proficiency are the following:

1. The inhibiting effect on undesirable male tendencies, based on the presence of a female, may tend to diminish as a function of time and increased familiarity.
2. There is a possibility that a real rivalry will begin to take place for the favors of a female, with dissention and combat arising.

3. The possibility has been advanced that the female of the system might choose to her liking one individual, with relative exclusion of the other. This could be represented as social or physical preference, or both.

4. The female could tend to experience a degree of loneliness for a companion of her own sex.

Although these and other factors exist as possibilities in the operation of the CVT, they can only be established as present and detrimental through testing. In selecting three as a basic number, consideration was given to the probability that four crew members with a ratio of 2:2, would perhaps be more optimal. However, weight restrictions may not permit such extravagance for life support and physical size of the CVT. The addition of one more crew members, for example, to form a team of two husbands and their wives, would result in a 30% increase in crew space, and a total ship weight increment of about 100,000 lbs. This may not be justifiable until the merits of small crews have been carefully investigated.

CVT TRAINING SCHEME FOR FUTURE CREW MEMBERS

The focus of interest in the training of the CVT space crews is the minuscule allowable error in equipment operator functioning. Such a required level of excellence demands indoctrination in every conceivable parameter of ecosystem functioning, a feat which is impossible at this stage of the space-flight program. Important in the preparation of each human for early missions will be the condition that he "make up the difference" for phenomena anticipated and prepared for, and those not recognized or entirely unknown.

The selected and voluntary crew will enter into the CVT prototype and space environment simulator with the conviction that it is "just another test on earth". But after a few weeks, during which every sensory perception would indicate a lunar environment.

the illusion will become more and more manifest until, depending on individual susceptibility, the auto-suggestion is more or less complete and the crew will believe themselves to be on the moon. Such an illusion can be greatly enhanced with post-hypnotic suggestion. There are numerous such experiences reported in the literature. To mention only one: many pilot students who have been in a Link trainer for prolonged time, when the instructor programs into the instruments crash conditions, will "bail out", and it is known that some were injured.

The conditions which the operator will face in real space environment are not exactly those which one will encounter in our highly developed simulator. Consequently, it is expected that there will be adjustments necessary even after thorough indoctrination and training, but it is expected that the elasticity and the adaptability of the human organism will be able to bridge these gaps.

The principle areas of training for the CVT can be subdivided into three parts: (1) survival indoctrination and habitation, (2) operation and maintenance of all equipment systems and sub-systems, (3) navigation and communications.

Preceded by comprehensive class indoctrination, these areas can be applied effectively in the ground-based simulator and later the navigational skills can be perfected in operational craft. The detailed outlining and special training and indoctrination technique will lean partially on upgraded flight requirements.

The situation becomes less simple as candidates begin to show fairly comparable performance levels under equally demanding stresses. It is then up to the tester to reveal, by even more punishing testing-training, the disabilities which could compromise a mission.

Without the use of test situations to rule out candidates, we may establish certain criteria for the elimination of personnel where at least these six personality characteristics fail to

emerge:

- 1) Uncritical appraisal of those in the work situation about him, based not on moralistic concepts but on realistic evaluation of peers and their level of proficiency, as seen in the light of their varied personal histories.
- 2) An intellectual orientation of outlook which can be partially shelved in favor of temporary conditions requiring deep emotional empathy with a fellow, for the good of his mental health.
- 3) Skill in observing the dynamics of the cabin social field as it relates to crew proficiency. This criterion implies a high degree of insight and honesty, especially in evaluating emergent group sub-systems and their influence on total system performance.
- 4) An attitude which expresses itself emotionally in a lively, pleasant, and stimulating source of confidence of the other members of the expedition, even in the face of deprivation.
- 5) Use of personal mental and physical resources as a source of pleasant reverie and entertaining self-stimulation.
- 6) Ability to tolerate a broad latitude of libido influence and satisfaction which may demonstrate itself in a symbolic and/or physical manner--both in himself and the other personnel.

Motivation on the part of the investigator, although thought to be genuine, must not be accepted without close scrutiny. For example, a good deal of such fervor may vanish upon reaching of some personal goal far less than what the planners of the mission consider minimal to its success.

The CVT must be operated by the personnel for varying periods, probably from one week and later up to six months. The question of utilizing different character types based on the length of the proposed mission seems optimistic. A crew chosen for a week's operation may end up existing in the CVT for several times the originally planned period. It is believed that each crew must be chosen as though it were to operate for the longest projected time, which, indeed, it could.

It would seem that the ultimate criterion for the choice of one crew over another would be over-all ability to succeed in the face of a CVT environment. To facilitate the assembly of optimal crews, careful placing of compatible trainees in three-person units is suggested. These units can be shuffled experimentally to achieve the highest end output. In this respect, the sex ratio of the crews is of little moment; one crew complement might differ from that of another equally acceptable unit. The functioning of one crew may involve idiosyncracies peculiar to that group only; what is important is group performance. Research in the CVT should provide the answer to questions of crew sex ratio.

The symbolic expression of sexual tendencies can be detrimental to the mission when:

- 1) By their overt nature, they impair the close interaction of the human and his machine system, with a corresponding proficiency attenuation.
- 2) By their distractive characters, they capture too much attention from one or more of the crew.
- 3) Their existence may draw from mental energy and attention-giving functions, thereby reducing receptivity to more important external and internal stimuli.

Discovering the manner of libido expression on the physical and psychological level of all candidates for lengthier space missions is a prime requirement. The sudden or gradual emergence of an objectionable trait or response while engaged in a flight or operation might lead to disaster in terms of proficiency.

Psychological tests, interviews, and observation of the history and the present performance of a candidate under CVT conditions opens the way for insight into recording of the basic tendencies in each individual's libido satisfaction. Such information could be utilized in the selection of crews, with a greater chance for optimal social relations and corresponding completion of the mission.

The fatigue accompanying individual acts in long duration periods is more complicated than the fatigue involved in short-term flights, because of the added cumulative effect. Libido emergence, according to the literature, does not come until there is a sufficient period of relatively stress-free relaxations. Even then, cumulative fatigue arising from earlier stress is a further deterrent to sexual tendencies until it is reduced. If some long-term operations are conducted under very demanding conditions over the entire length of the mission, we might expect more difficulty from fatigue resulting from stress, boredom, repetition, etc., than from non-existent or transient libido influences.

Nevertheless, sexual energy may seek to manifest itself in some or all of the crew members at any point along the continuum of an only seven-day mission, no matter how strenuous they are observed to be. Absorbing fantasy, channeling of thoughts resulting in decreased proficiency, and other symptoms of the libido drive would have to be curbed by training and desire to complete the mission successfully.

The optimization of the crew number in the research work yields an approximation for two man and one woman. In this configuration, it must be assumed that all crew members have some knowledge in each other's research project; thus, any one of them can assist the other in his experiment.

APPENDIX F

Psychological factors which have pertinence in the evaluation of the experiment with food acceptance and crew performance in the CVT System.

- 1) Anorexia
- 2) Anxiety due to libido repression
- 3) Frustration
- 4) Dream-displacement
- 5) Delusions due to sensory deprivation
- 6) Homosexuality
- 7) Neurasthenia
- 8) Neuroses due to conflict of ego and id
- 9) Hypochondria